Population Review

Volume 58, Number 1, 2019

Type: Article, pp. 1-19

Application of Population Models to the Adjustment of Age and Sex Data from Developing Countries

Authors: C.O. Okoro and E.C. Nwogu

Affiliations: Department of Statistics, Imo State University, Owerri, Nigeria (Okoro); Department of Statistics, Federal University of Technology, Owerri, Nigeria (Nwogu)

Corresponding author/address: C.O. Okoro, Department of Statistics, Imo State University, Owerri, Nigeria; email: chinonso.okoro@yahoo.com

Abstract

This paper focuses on the adjustment of reported populations from censuses in developing countries. Reported populations by sex and 5–year age groups in censuses from developing countries are known to be defective and need adjustment before they can be gainfully utilised. We apply methods based on population models to obtain adjusted populations from the reported populations because mathematical methods have been shown to smoothen out genuine features of a study population. In order to assess the success of the adjustment, the adjusted data were subjected to re-evaluation and were used to obtain estimates of some demographic parameters (fertility, mortality, etc). Using the age-sex accuracy index, the results show that quality of the adjusted populations improved substantially in all the censuses and appear much better than results from the mathematical methods. Therefore, we recommend that, where necessary, adjusted data using population models should be used for estimation of demographic parameters and population projections in developing countries.

Keywords

Adjustment, age and sex data, Nigeria, age misreporting, base population, population models

1. Introduction

Distribution of population by age and sex forms the basis for population projection and estimation of demographic parameters (e.g., fertility, mortality, migration and socio-economic characteristics, such as nuptiality, education and employment, among others) required for planning, implementation and monitoring of development plans. The main sources of demographic data on age and sex are population censuses and sample surveys. However, in most developing countries, demographic data from these sources are defective. According to Ramachandran (1989), the error most commonly found in such data is age misreporting. The types of age misreporting often observed in age and sex data from developing countries are: (i) digit preference; (ii) age shifting across critical age boundaries; and (iii) age exaggeration. These affect adversely the quality of the estimates from the data unless something is done to improve the quality of the data. As a result, adjustment of demographic data has become an integral part of demographic data analysis in order to improve the quality of estimates of demographic parameters.

In developing countries, quality of age and sex data has been shown to be very poor by many researchers (Ekanem 1972; Nwogu 2006, 2011; Dahiru and Dikko, 2013; Ohaegbulem 2015). Data quality is often measured by the United Nations joint score index. UN (1955) joint Score is an index for evaluating the empirical relationship between sex-ratio and age-ratio scores. It is computed as a weighted sum of the Age Ratio Score (ARS) and Sex Ratio Score (SRS) of a study population. The index score considers census data to be accurate if the joint score index is ≤ 19, inaccurate if in the range of 20 - 40 and highly inaccurate if greater than 40 (Ramachandran 1989). Nwogu (2006) observed that in all the censuses and survey data on age and sex in Nigeria, between 1963 and 2003, the minimum value of the UN joint score was 45.9 (obtained in 2003 from the Nigeria Demographic and Health Survey). Nwogu (2011) also found that the UN joint scores are 38.52 for the 2006 Nigerian census and 34.72 for the 2008 Nigeria Demographic and Health Survey. Ohaegbulem (2015) observed the joint scores of 54.83 for the 1991 Nigerian census and 38.52 for the 2006 Nigerian census. Thus, all of the observed UN joint scores above show that the data sets in Nigeria are, at best, deficient but may be useable with adjustment.

The ultimate objective of this study is to obtain adjusted age and sex distributions for the 1963, 1991 and 2006 Nigerian censuses, which may be used to improve the estimates of the demographic parameters in Nigeria (these are the only Censuses in Nigeria in that time period). The specific objectives are: (i) to choose an appropriate standard (model) population to adjust the Census data, (ii) to adjust the age-sex distribution of population using the model population, and (iii) to assess the adjusted age-sex data for adequacy of the adjustment.

2. Methodology

2a. Research design

Data for this study come from the Nigerian censuses of 1963, 1991 and 2006. The dataset, consisting of population distribution by sex and in 5-years age groups, was collected by the National Population Commission (NPC) of Nigeria (NPC 2009) and extracted from the UN dataset website (data.un.org/data).

2b. Data measurement

We use methods based on population models because mathematical methods have been shown to smoothen out genuine features of a population. For details of mathematical methods see ECA (1988). Methods of adjustment based on population models most commonly in use are the Brass Logit transformation and the Y-Transformation (UN 1956, 1983).

In the Brass logit method, the proportion of the study population under age x ($C(\mathrm{x})$), is transformed by logit ($L(x)$) as

$$L(\mathrm{x}) = \frac{1}{2}\ln\left(\frac{C(\mathrm{x})}{1-C(\mathrm{x})}\right) \tag{2.1}$$

For $0 \le \mathrm{C(x)} \le 1$, it is clear that $-\infty < L(x) < \infty$. Thus, the age distribution of population is transformed to make it a linear function of age. A similarly transformed age distribution of a standard population $L^s(\mathrm{x})$ is also a linear function of age:

$$L^s(\mathrm{x}) = \frac{1}{2}\ln\left(\frac{C^s(\mathrm{x})}{1-C^s(\mathrm{x})}\right) \tag{2.2}$$

Since $L(\mathrm{x})$ and $L^s(\mathrm{x})$ are linear functions of x, $L(\mathrm{x})$ can also be written as a linear function of $L^s(\mathrm{x})$. Thus,

$$\mathrm{L(x)} = \alpha + \beta\,\mathrm{L}^s(\mathrm{x}) \tag{2.3}$$

where α and β are constants denoting, respectively, the level and age pattern of mortality in the study population relative to the standard. Estimates; $\hat{\alpha}$ and $\hat{\beta}$ of α and β can be derived from the study data and standard population distribution by any of the known regression procedures (e.g., the group mean method, Least Squares Method (LSM) etc.). Having obtained the estimate of α and β, the estimate of the proportion of population (the adjusted population) under age x is given by

$$\hat{C}(\mathrm{x}) = \frac{\exp\left[2\hat{L}(x)\right]}{1+\exp\left[2\hat{L}(x)\right]} \tag{2.4a}$$

where

$$\hat{L}(\mathrm{x}) = \hat{\alpha} + \hat{\beta}L^s(\mathrm{x}) \tag{2.4b}$$

However, it has been shown in some applications using logit transformation that smoothing at very early and late ages is not quite satisfactory. For a given proportion ($C(\mathrm{x})$) of a population under age x, UN (1983) defined the Y- transformation as

$$Y(\mathrm{x}) = \ln\left(\frac{1+C(\mathrm{x})}{1-C(\mathrm{x})}\right) \tag{2.5}$$

Like the logit transformation ($L(\mathrm{x})$), Y(x) has also been shown to be a linear function of age (x). However, unlike $L(\mathrm{x})$, for $0 \le \mathrm{C(x)} \le 1$, $0 \le \mathrm{Y(x)} \le \infty$, that means Y(x) is non-negative.

Similarly, for a given standard population with age distribution $C^s(\mathrm{x})$, the Y-transformation, given by

$$Y^s(\mathrm{x}) = \ln\left(\frac{1+C^s(\mathrm{x})}{1-C^s(\mathrm{x})}\right) \tag{2.6}$$

is also a linear function of x and $0 < Y^s(x) < \infty$. That is, $Y(x)$ can be expressed as a linear function of $Y^s(x)$. However, since both are zero at x = 0 the intercept is zero, UN (1983) suggested that $Y(x)$ can also be written as second degree function of $Y^s(x)$. That is

$$Y(x) = A\left[Y^s(x)\right]^2 + B\left[Y^s(x)\right] \tag{2.7}$$

where A and B are constants whose estimates can be derived by any of the regression methods. Estimates $\hat{A}$ and $\hat{B}$ of A and B, obtained using the group mean method are

$$\hat{A} = \frac{1}{\left[\overline{Y}_2^{(s)} - \overline{Y}_1^{(s)}\right]}\left[\frac{\overline{Y}_2}{\overline{Y}_2^{(s)}} - \frac{\overline{Y}_1}{\overline{Y}_1^{(s)}}\right] \tag{2.8}$$

$$\hat{B} = \frac{\overline{Y}_1}{\overline{Y}_1^{(s)}} - \hat{A}\,\overline{Y}_1^{(s)} \quad \text{or} \quad \frac{\overline{Y}_2}{\overline{Y}_2^{(s)}} - \hat{A}\,\overline{Y}_2^{(s)} \tag{2.9}$$

Hence, estimates of $Y(x)$ and $C(x)$ are respectively, given as

$$\hat{Y}(x) = \hat{A}\left[Y^s(x)\right]^2 + \hat{B}\left[Y^s(x)\right] \tag{2.10}$$

$$\hat{C}(x) = \frac{\exp\left[\hat{Y}(x)\right] - 1}{\exp\left[\hat{Y}(x)\right] + 1} \tag{2.11}$$

In this study, only the Y transformation is used for the reason earlier stated.

2c. Choice of appropriate standard population

From Sections 2a and 2b, it is clear that the reliability of $\hat{C}(x)$, both in the logit and in Y-transformations, depends on the choice of appropriate standard population. Economic Commission for Africa (1988) noted that the appropriate standard population may be a model population or analogies. To choose an appropriate model population, Brass (1975) suggested the use of probability of a newborn surviving to age 5 (l_5) obtained from data on mean number of children dead among children everborn and the rate of growth (r) of the study population as entry parameters. However, for a given pair of l_5 and r, there are a number of schedules of $C^s(x)$ to be chosen from. In the present study, our preference is for the schedule with the minimum mean absolute deviation of $C^s(x)$ from the schedule $C(x)$ of proportions of the study population. In the analogy, the age - sex distribution is borrowed from the experience of another country or area which has similar demographic evolution but has better quality data.

To choose the appropriate population model from the Coale-Demeny model life table, the l_5 derived by Nwogu and Nweke (2016) from the 2013 NDHS and the population growth rate (r) of about 2.9% for Nigeria given by Federal Government of Nigeria (2004) were used as entry parameters. The l_5 derived by Nwogu and Nweke (2016) suggested the use of level 15.14 of North model. This, in combination with r = 2.9%, show that the appropriate standard lies between levels 15 and 16 of the North model of the Coale-Demeny stable population, while r lies between 2.5% and 3.0%. The mean absolute deviations of the $C^s(x)$ from $C(x)$ for pairs of levels and growth rates (15, 2.5%), (15, 3.0%), (16, 2.5%) and (16, 3.0%) is minimum for r = 3.0% in level 15 North of the Coale-Demeny stable population.

The age-sex distribution of population of Ghana was also used as a standard for adjustment of the population of Nigeria because Ghana is known to have similar demographic evolution as Nigeria, but with relatively better demographic data quality. Therefore, the adjustment of Nigeria populations by Y-transformation was done using both stable population and the age-sex distribution of population the 2010 Ghanaian census as standards. Life Table functions for both sexes were derived from sex specific ones using sex ratio at birth (SRB) of 1.05.

3. Results

In Section 3, the methods outlined above in Section 2 are applied to the census data in Nigeria. Section 3a considers the application of Y-transformation to the adjustment of reported population by sex and 5-year age groups, as shown in Table 7 (see Appendix 2a to the present document), while Section 3b presents the assessment of adequacy of the adjusted of populations.

3a. *Application of the Y-transformation*

The Y-transformed study population (Y(x)) and the Y-transformed standard population (Ys(x)) are given in Tables 8 through 11 while the plots of reported and adjusted against Age for the Nigerian populations using stable population and 2010 Ghana population as standards are shown in Figures 4 through 9 (see Appendix 1b -1c and Appendix 2b -2c to the present document), whereas the plots of Y(x) against Ys(x) are shown in Figures 1 through 3 (see Appendix 1a to the present document), for the three censuses. As the Figures show, a linear relationship exists between them that pass through the origin in all the surveys, which indicates that the chosen standard may be appropriate.

The details of application of Equations (2.8) through (2.11) to the reported populations in Table 7 are given in Table 1. And Tables 8 through 11 show the adjusted populations by 5-year age groups using Stable population, and the 2010 Ghanaian census population as a standard (see Appendix 2b and 2c to the present document).

Table 1. Estimate of parameters of regression equation of Y(x) on Ys(x)

Parameter	1963		1991		2006	
	M	F	M	F	M	F
$\hat{A}$	0.04297	0.13639	-0.0093	0.08169	0.0147	0.08879
$\hat{B}$	0.9005	0.8667	1.0051	0.9124	0.9229	0.8509

Source: Author computations from Nigeria Census datasets

As Tables 2 and 8 show, reported populations of males under 5-years are less than the corresponding adjusted populations, while reported populations aged 5 - 9 years are greater than the corresponding adjusted populations using stable population as a standard. Table 2 (next page) also shows that the reported male populations aged 65 – 69 appear to be lower than the adjusted populations.

For the female, the reported populations under 10 years appear to be higher than the adjusted, indicating over-reporting of the population in all the surveys. On the other hand, the reported populations aged 10 – 19 years for both sexes appear lower than the adjusted population in all the surveys except for 1963 census.

3b. *Assessment of adequacy of the adjustment*

Assessment of adequacy of adjustment is done in this section by re-evaluation of the adjusted population and calculation of estimates of some demographic parameters consistent with the adjusted population. This is important to see if there is any improvement in the quality of the adjusted data.

Table 2. Adjusted populations of Nigeria censuses using stable population as a standard

	Male			Female		
Age(x)	1963	1991	2006	1963	1991	2006
0-4	4,731,434	8,099,643	12,045,609	4,489,177	7,445,058	10,857,274
5-9	4,049,941	6,519,740	9,937,638	4,037,565	6,434,665	9,521,849
10-14	3,571,543	5,460,702	8,539,217	3,675,899	5,696,550	8,569,787
15-19	3,134,847	4,603,084	7,380,445	3,279,086	4,996,337	7,650,970
20-24	2,698,391	3,853,655	6,324,214	2,843,190	4,308,137	6,719,261
25-29	2,287,463	3,221,664	5,397,376	2,390,409	3,644,415	5,789,485
30-34	1,905,648	2,686,524	4,580,200	1,950,910	3,029,081	4,899,204
35-39	1,560,076	2,237,360	3,867,486	1,536,993	2,461,158	4,049,791
40-44	1,251,735	1,859,656	3,245,585	1,167,421	1,954,160	3,268,073
45-49	976,217	1,534,914	2,691,118	852,793	1,515,351	2,572,610
50-54	731,163	1,249,143	2,186,411	586,485	1,126,915	1,939,511
55-59	523,727	1,006,578	1,744,415	377,303	802,943	1,398,736
60-64	343,495	779,295	1,321,780	216,041	526,430	926,353
65-69	203,492	585,166	954,611	105,066	307,678	545,360

Source: Author computations from Nigeria census datasets.

Table 3. Adjusted populations of Nigeria censuses using the population of the 2010 Ghana census as the standard

Age	Male			Female		
(x)	1963	1991	2006	1963	1991	2006
0-4	4,354,808	7,490,570	11,154,767	4,203,623	7,131,200	10,299,757
5-9	4,063,447	6,600,213	10,032,731	3,984,598	6,415,674	9,466,204
10-14	3,801,220	5,841,179	9,100,101	3,767,392	5,792,795	8,758,819
15-19	3,357,507	4,917,182	7,864,324	3,372,817	5,005,021	7,763,042
20-24	2,774,499	3,922,885	6,433,781	3,077,834	4,471,189	7,111,207
25-29	2,315,498	3,208,977	5,383,222	2,630,465	3,810,833	6,204,731
30-34	1,870,066	2,581,188	4,415,724	1,944,845	2,872,368	4,766,385
35-39	1,527,053	2,135,766	3,713,379	1,470,151	2,262,579	3,804,168
40-44	1,216,720	1,758,607	3,096,155	1,068,671	1,753,456	2,969,631
45-49	895,216	1,366,189	2,424,535	730,099	1,305,955	2,213,695
50-54	713,415	1,181,099	2,101,902	553,048	1,111,326	1,871,776
55-59	422,056	777,481	1,379,371	275,586	635,570	1,056,290
60-64	330,114	694,953	1,221,428	211,156	567,665	925,040
65-69	173,826	430,159	744,373	106,553	343,023	544,140

Source: Author computations from Nigeria census datasets.

3c. Re-evaluation of adjusted data

The re-evaluation of the adjusted data was done by calculating the age-sex accuracy indices from the adjusted data. The results, shown in Table 4 (next page), indicate that the values of the joint score for the adjusted data, while still lying between 20 and 40, are smaller than the corresponding values from the reported data and adjusted data using mathematical methods in almost all the surveys.

Table 4. Summary of indices measuring the accuracy of data

		Adjusted Population by				
		Population models		Mathematical Methods		
Index/Year	Reported population	Stable Population	Ghana 2010 Census	Carrier & Farrag	Newton	United Nations
1963						
Sex ratio score	14.44	9.18	7.99	6.85	7.53	7.66
ARS : Male	33.27	0.84	2.78	7.28	7.76	6.56
ARS : Female	40.74	1.51	4.08	11.61	12.09	8.90
Joint score	117.33	29.89	30.83	39.45	42.43	38.43
1991						
Sex ratio score	21.61	9.93	6.11	7.18	7.67	7.32
ARS : Male	21.91	0.73	3.04	2.69	2.82	3.19
ARS : Female	27.79	0.62	4.12	4.79	4.89	4.22
Joint score	87.54	31.14	25.49	29.03	30.72	29.37
2006						
Sex ratio score	8.96	8.02	6.11	7.3	7.63	7.29
ARS : Male	15.15	0.55	2.97	2.25	2.26	2.28
ARS : Female	17.71	0.69	4.05	4.66	4.89	4.16
Joint score	59.73	25.30	25.35	28.82	30.05	28.30

Note: The Joint Score was calculated using age range 10-69, ARS = Age Ratio Score. The mathematical methods estimates were lifted from (Nwogu and Okoro 2017).

Using stable population as standard, the joint score dropped from the reported value of about 117.33 to 29.89 in the 1963, 87.54 to 31.14 in the 1991 and 59.73 to 25.30 in the 2006 censuses. Similar results are observed using the 2010 Ghana population as a standard population in all the surveys and indices. However, reductions in the joint score using the 2010 Ghana population as standard appear more consistent than the using stable population as standard.

3c. Estimate of fertility measures consistent with the adjusted populations

Estimates of fertility measures – Crude Birth Rates (CBRs) and Child-Woman Ratios (CWRs) – based on the adjusted populations are shown in Table 3, while comparing them with the corresponding reported measures and from other notable sources such as United Nations. As Table 3 shows, CBRs from the adjusted population seem to be lower than those from the reported population in all the censuses. The Child-Woman Ratios (CWRs) from the adjusted populations, on the other hand, appear to be consistently higher than those from the reported populations in all the surveys except in 1963.

Table 5. Comparison of crude birth rates (CBR) from the reported and adjusted populations

Census/ Year	Reported CBR (‰)	Adjusted CBR (‰) by					
		Population models		Mathematical	Other sources		
		Adjusted1	Adjusted2	*Adjusted	UN	US(CB)	WB
1963	66.0	43.2	42.6	42.1	46.24	46.0	46.12
1991	44.6	43.7	43.3	44.0	43.75	44.0	44.04
2006	-	41.5	41.0	41.0	41.94	41.0	42.33

Note: $Adjusted_1$: Estimates of fertility measures from adjusted population using stable population; $Adjusted_2$: estimates of fertility measures using Ghana 2010 population; UN - United Nations; USCB - US Census Bureau; WB: World Bank; CBR- Crude Birth Rate; *Adjusted: estimates lifted from (Nwogu and Okoro 2017).

Table 6. Comparison of child-woman ratios (CWRs) from the reported and adjusted populations

Census / Year	Reported CWR (%)	Adjusted CWR (%) by		
		Population models		Mathematical
		Adjusted1	Adjusted2	*Adjusted
1963	66.2	65.8	59.9	67.5
1991	67.6	71.0	68.1	76.2
2006	64.6	65.5	65.5	68.2

Note: $Adjusted_1$: Estimates of fertility measures from adjusted population using stable population; $Adjusted_2$: estimates of fertility measures using Ghana 2010 population; CWR- child-woman ratio; *Adjusted: estimates lifted from (Nwogu and Okoro, 2017).

4. Discussion

In summary, the linear relationship between the Y-transformed study and standard populations, which passes through the origin in all the surveys, indicate that the chosen standards may be appropriate. This is true using Stable population and the 2010 Ghanaian census population as a standard. The choice of appropriate standard population is critical to the right adjustment.

Using stable population as a standard, reported populations of males under 5 years are less than the corresponding adjusted populations, while the reported populations aged 5 - 9 years are greater than the corresponding adjusted populations. These results indicate that the population of males under 5 years may have been under-reported, while the population of males aged 5 - 9 years may have been over-reported in all the surveys. The problems of under-reporting of population under 5 years and over-reporting of population aged 5 – 9 years have been widely reported in most developing countries (Ramachandran 1989). These have been attributed, in part, to sharp practices by parents to enroll their wards under 5 years into post-nursery meant for those aged 6 years and above. Table 2 also shows that the reported male populations aged 65 – 69 appear to be lower than the adjusted populations, indicating under-reporting of population in all the surveys. Ramachandran (1989) attributes this to envisaged end benefits such as tax exemption. For the female, the reported populations under 10 years appear to be higher than the adjusted, indicating over-reporting of the population in all the surveys. On the other hand, the reported populations aged 10 – 19 years for both sexes appear lower than the adjusted population in all the surveys except for 1963 census, which indicates that the age range may have been under-reported.

From the results of the re-evaluation of the adjusted data, one can surmise that the values of the joint score for the adjusted data are smaller than the corresponding values for the reported data in all the censuses, indicating that there is improvement in the qualities of the adjusted data in all the censuses. This is true using both stable populations and the 2010 Ghana population as standard. However, a drop in the joint score using the 2010 Ghana population as standard appears more consistent than the score using stable population as standard. Estimates of fertility measures – CBRs and CWRs – based on the adjusted populations appear to be more consistent with those presented by the United Nations and seem to be lower than the reported CBRs in all the censuses. The CWRs from the adjusted populations appear to be consistently higher than those from the reported populations in all the surveys, except in 1963, indicating that the reported population may have overstated the fertility levels in the country. Thus, it appears that the adjusted population had a positive effect on the quality of data.

5. Conclusion and recommendations

The present study has discussed the adjustment of population distribution by age and sex from developing countries. Population distributions by age and sex, which provide base populations for estimation of demographic parameters, have been shown to be defective in developing countries. Therefore, in order to provide base populations for improved estimates of demographic parameters, adjustments are required.

Method of Y-transformation has been applied to obtain adjusted populations from the reported populations by sex and 5-year age groups in the 1963, 1991 and 2006 Nigerian censuses. In order to assess the adequacy of the adjustment, the adjusted populations were subjected to re-evaluation and were used to obtain estimates of some demographic parameters (CBR, CWR, etc).

The results of the re-evaluation of the adjusted population show that the quality of the adjusted data has improved. The age-sex accuracy indices dropped substantially from the reported to the adjusted populations from the 1963, 1991 and 2006 censuses. Furthermore, estimates of demographic parameters also improved and appear more consistent with estimates from other independent sources, especially those from the United Nations. Quality of adjusted populations derived by this method also appears to be better than those derived using mathematical methods.

In view of the above, the method of Y-transformation has been recommended to obtain adjusted population from reported population when age misreporting is highly pronounced, as observed in the study data. It is important to note that no amount of adjustment can atone for the distortions in the demographic data. It is wrong to ignore careful and cautious field operational methodology simply because errors can be corrected by adjustment. Therefore, in future censuses and surveys, efforts should be made to minimise the errors in the field instead of waiting for data adjustment. This could be achieved through increased sensitization and education of study population, adequate training, close supervision and remuneration of enumerators during the field operation. Enumerators should also be encouraged to check deliberate misstatement of age and to extract age data from birth registration certificates. This is because the usual practice of eliciting information on every members of a household from the head may be responsible for some of the distortions in the demographic data.

Furthermore, the choice of an appropriate standard population should be done with caution to avoid undermining the essence of data correction. As noted earlier, the choice of a wrong standard will lead to wrong adjustment. If these suggestions are considered and implemented, improved base populations, and hence improved estimates of demographic parameters will be achieved.

References

Brass, Williams (1975). "Methods for Estimating Fertility and Mortality from Limited and Defective Data." Laboratories for Population Statistics, University of North Carolina, Chapel Hill.

ECA (1988). "Workbook on Demographic Data Education and Analysis based on ECA Sub Regional Training Workshop for Anglophone Countries", held at RIPS, Accra.

Ekanem, I.I. ed. (1972). *The 1963 Nigeria Census: A critical Appraisal.* The Croxton Press (West Africa) Limited, Ibadan.

Dahiru, T. and Hussani G. Dikko (2013). "Digit preference in Nigerian censuses data of 1991 and 2006," *Epidemiology Biostatistics and Public Health* 2 (10):1-5. https://doi.org/10.2427/8843

Federal Government of Nigeria (2004). *National Policy on Population for Sustainable Development.*

National Population Commission (2009). "Population and Housing Census of the Federal Republic of Nigeria."

Nwogu, Eleazar C. (2011). "Evaluation of Qualities of Age and Sex Data in the 2006 Nigeria Census and 2008 Nigeria Demographic and Health Survey." *Journal of the Nigerian Statistical Association* 23: 23-56.

Nwogu, Eleazar C. (2006). "Quality of Demographic data in Nigeria: Problems and Prospects." *Global Journal of Pure and Applied Sciences* 12:99-106.

Nwogu, Eleazar. C. and Iwueze, S.Iheanyi (2009). *Introduction to Demography*. Supreme Publishers, Owerri, Imo State, Nigeria.

Nwogu, Eleazar C. and Nweke, J.Chijioke (2016). "Levels and trend of Under-Five Mortality in Nigeria: Evidence from NDHS Data." *FUTO Journal of Science* 2:205-217.

Nwogu, Eleazar C. and Okoro, O. Chinonso (2017). "Adjustment of Reported Populations in Nigeria Censuses using mathematical methods." *Canadian Studies in Population* 44(3-4): 149-64.

Ohaegbulem, Emmanuel U. (2015). "A reliability assessment of the age-sex data from 1991 and 2006 Nigeria population censuses." *International Journal of Advanced Statistics and Probability* 3 (2): 132-137.

Ramachandran, K.V. (1989). "Errors and Deficiencies in Basic Demographic Data: Overview of methods of Detection, Evaluation and Adjustment in Fertility and mortality Estimation in Africa." Proceedings of a Workshop on the estimation of fertility and Mortality in Africa, held at RIPS, University of Ghana

United Nations (1955). "Manual II: Methods of appraisal of quality of basic data for Population estimates." *Population Studies*, No. 56.XII.2, Department of Economic and Social Affairs, New York.

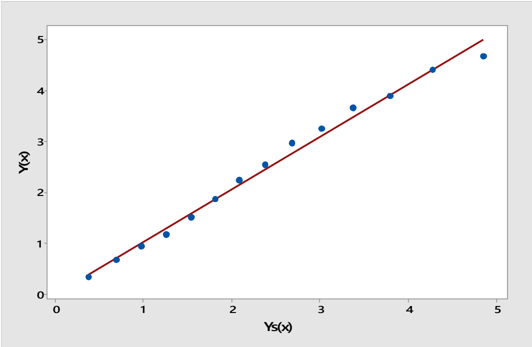
United Nations (1956). "Manual III: Methods for Population Projections by Sex and Age." *Population Studies*, No. 25, Department of Economic and Social Affairs, New York.

United Nations (1983). "Manual X: Indirect techniques for demographic estimation." Population Division, ST/ESA/SER.A/81, New York.

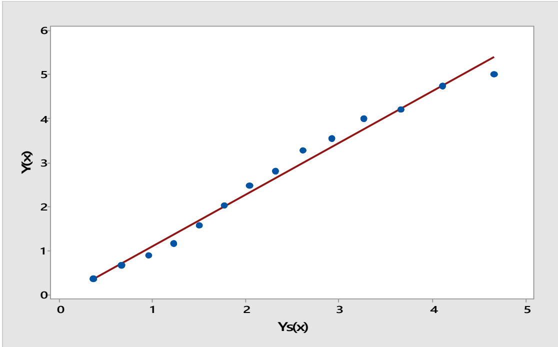
United Nations, Data Set website:www.data.un.org/data Accessed May 11, 2017

United State of America Census Bureau https://www.census.gov/population/international/data/idb/region.php?N=%20Results%20&T=13&A=separate&RT=0&Y=1981,1982,1990,1999,2003,2006,2008&R=-1&C=NI Accessed May 11, 2017.

Appendix 1a. Plots of Y(x) against Ys(x) for the Nigeria Census Populations

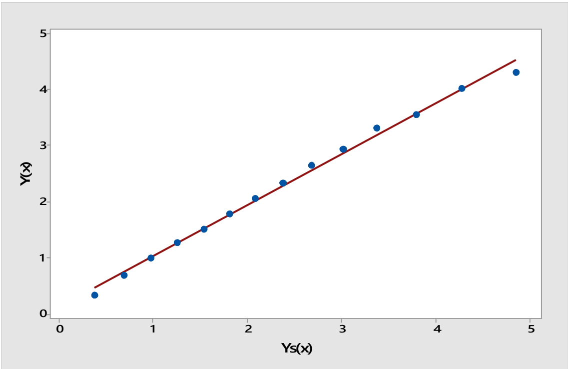


(a) Male

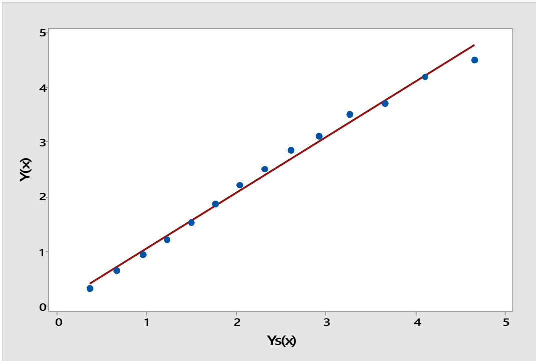


(b) Female

Fig 1. Plot of Y(x) against Ys(x) for the 1963 Nigeria Populations

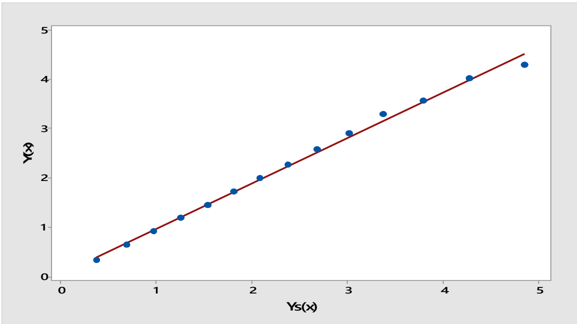


(a) Male

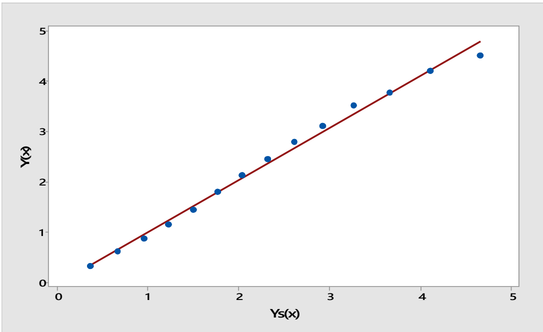


(b) Female

Fig 2. Plot of Y(x) against Ys(x) for the 1991 Nigeria Populations



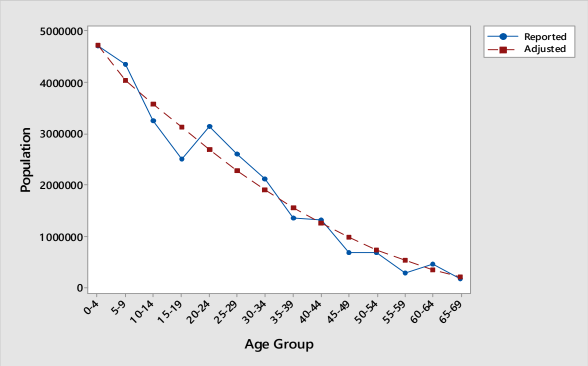
(a) Male



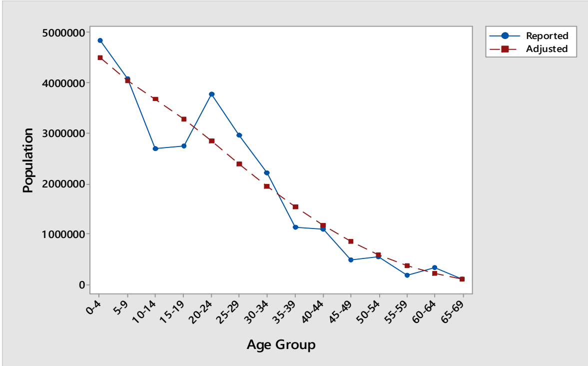
(b) Female

Fig 3. Plot of Y(x) against Ys(x) for the 2006 Nigeria Populations

Appendix 1b. Plots of the reported and adjusted populations against age using stable population

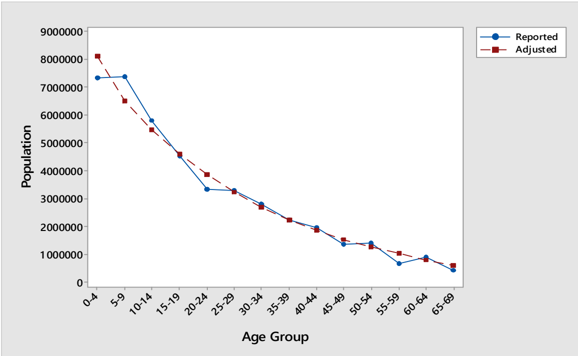


(a) Male

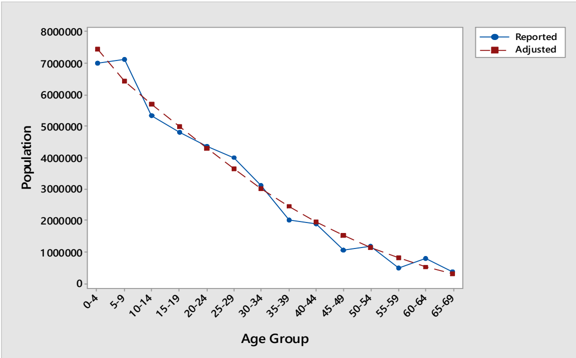


(b) Female

Fig 4. Plot of the reported and adjusted 1963 populations against age using stable population as standard



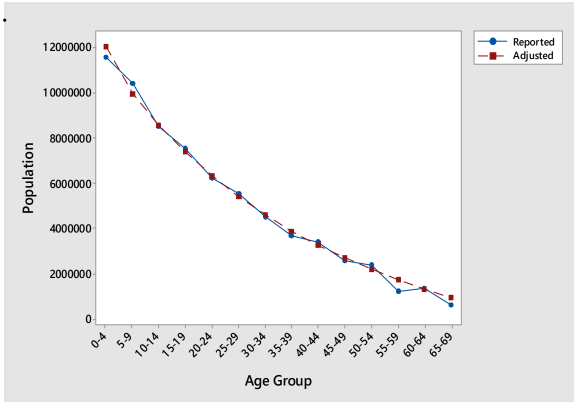
(a) Male



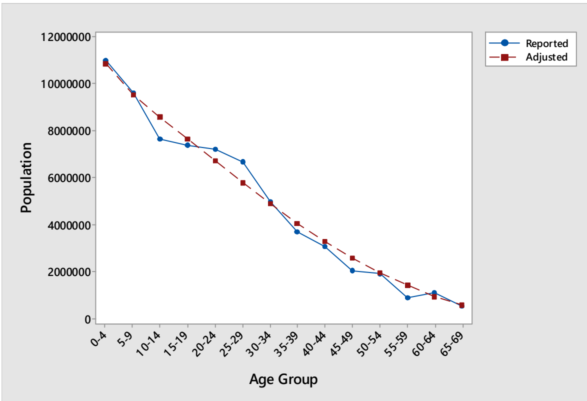
(b) Female

Fig 5. Plot of the reported and adjusted 1991 populations against age using stable population as standard

.



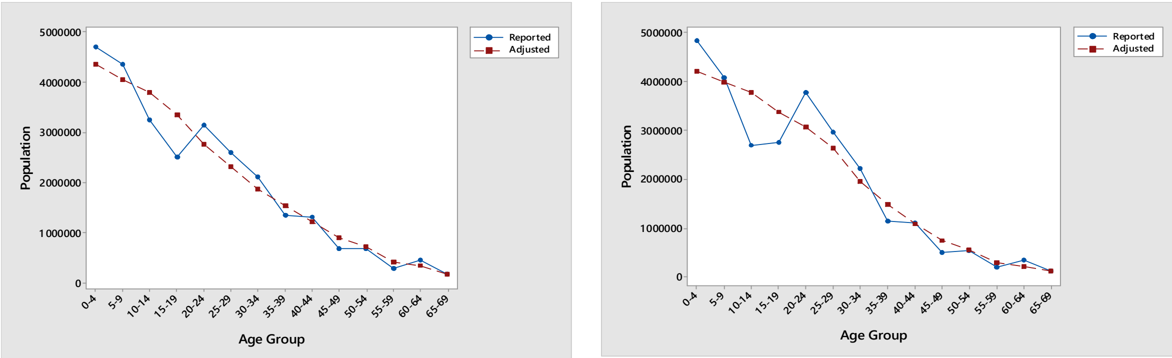
(a) Male



(b) Female

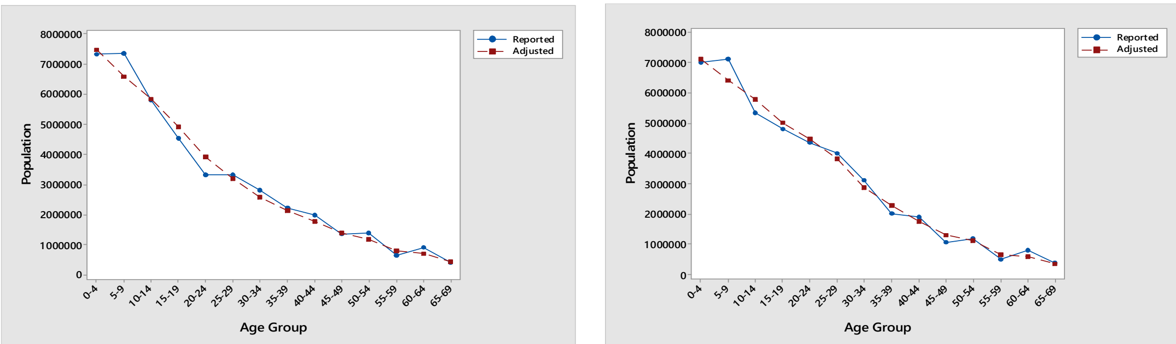
Fig 6. Plot of Reported and Adjusted against Age for the 2006 Nigeria Populations using model stable as a standard

Appendix 1c. Plots of Reported and Adjusted against Age for the Nigerian Populations using 2010 Ghana population as standard



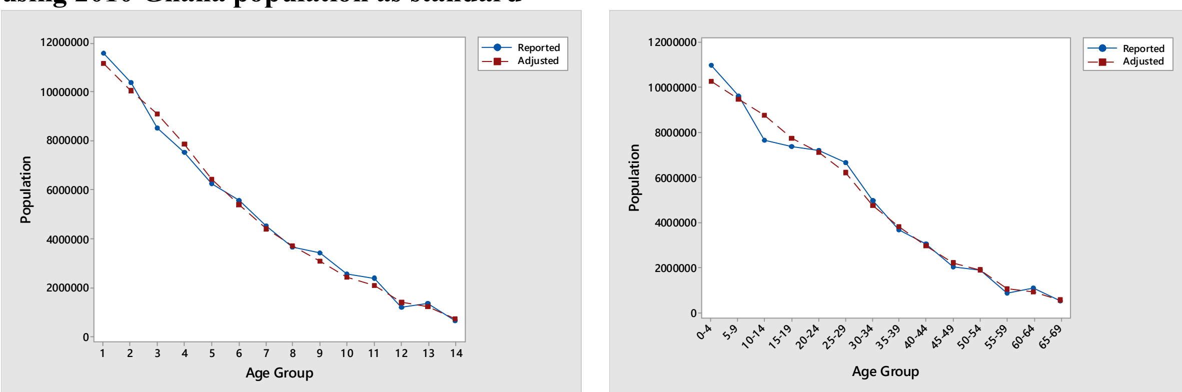
(a) Male (b) Female

Fig 7. Plot of Reported and Adjusted against Age for the 1963 Nigeria Populations using 2010 Ghana population as standard



(a) Male (b) Female

Fig 8. Plot of Reported and Adjusted against Age for the 1991 Nigeria Populations using 2010 Ghana population as standard



(a) Male (b) Female

Fig 9. Plot of Reported and Adjusted against Age for the 2006 Nigeria Populations using 2010 Ghana population as standard

Appendix 2a

Table 7. Reported populations in Nigeria Census by Age and Sex

Age (X)	1963		1991		2006	
	Male	Female	Male	Female	Male	Female
0-4	4,709,918	4,839,245	7,344,454	6,999,435	11,569,218	11,025,749
5-9	4,360,920	4,078,378	7,374,314	7,126,144	10,388,611	9,616,769
10-14	3,254,573	2,682,552	5,812,538	5,336,143	8,504,319	7,631,631
15-19	2,501,434	2,749,750	4,528,721	4,806,977	7,536,532	7,362,887
20-24	3,153,836	3,769,352	3,314,303	4,357,267	6,237,549	7,197,530
25-29	2,606,386	2,964,199	3,304,739	4,006,932	5,534,458	6,676,968
30-34	2,110,969	2,214,629	2,808,629	3,105,298	4,505,186	4,962,352
35-39	1,340,277	1,138,169	2,206,871	2,007,882	3,661,133	3,670,622
40-44	1,308,671	1,101,473	1,971,197	1,874,721	3,395,489	3,060,981
45-49	682,464	485,584	1,355,101	1,061,332	2,561,526	2,029,767
50-54	682,577	534,322	1,388,650	1,182,149	2,363,937	1,885,282
55-59	277,241	186,235	638,555	481,394	1,189,770	876,477
60-64	447,156	338,636	898,711	791,573	1,363,219	1,087,067
65-69	161,793	111,106	406,540	357,400	628,436	522,612

Source: UN dataset website (data.un.org/data).

Appendix 2b

Table 8. Estimation of parameters of Y-Transform for Female Populations using model stable population as standard

Age	C(x)			Cs(x)	Y(x)			Ys(x)						
(x)	1963	1991	2006		1963	1991	2006		1963	1991	2006	1963	1991	2006
5	0.1756	0.1574	0.1596	0.1776	0.3549	0.3175	0.3219	0.359	0.3287	0.3381	0.3169	0.1629	0.1674	0.1572
10	0.3236	0.3177	0.2988	0.3221	0.6713	0.6582	0.6164	0.668	0.6398	0.6459	0.608	0.3094	0.3122	0.295
15	0.4209	0.4377	0.4093	0.444	0.8977	0.9388	0.8694	0.9544	0.9514	0.9452	0.893	0.4428	0.4403	0.419
20	0.5207	0.5458	0.5158	0.5472	1.1546	1.2248	1.1413	1.2288	1.2709	1.2444	1.1797	0.5618	0.5527	0.5298
25	0.6575	0.6438	0.6200	0.6343	1.5768	1.5294	1.4501	1.4972	1.6033	1.5491	1.473	0.665	0.6496	0.627
30	0.7651	0.7339	0.7167	0.7075	2.0166	1.8745	1.8015	1.7643	1.9537	1.864	1.7777	0.7517	0.7315	0.7108
35	0.8454	0.8038	0.7885	0.7689	2.4797	2.2185	2.1349	2.0353	2.3289	2.1953	2.0997	0.8225	0.7997	0.7817
40	0.8867	0.8489	0.8416	0.8201	2.8127	2.5048	2.4534	2.3142	2.7362	2.5489	2.4448	0.8783	0.855	0.8404
45	0.9267	0.8911	0.8859	0.8626	3.2688	2.8546	2.8053	2.6068	3.1862	2.9335	2.8216	0.9206	0.899	0.8877
50	0.9443	0.915	0.9153	0.8978	3.5528	3.1146	3.1186	2.9215	3.6962	3.3627	3.2439	0.9516	0.933	0.9249
55	0.9637	0.9416	0.9426	0.9265	3.9906	3.5034	3.5217	3.2662	4.2858	3.8514	3.7265	0.9728	0.9584	0.953
60	0.9705	0.9524	0.9553	0.9497	4.2	3.7139	3.778	3.6574	4.9943	4.4296	4.3000	0.9865	0.9764	0.9732
65	0.9827	0.9702	0.971	0.9678	4.7438	4.1914	4.2197	4.1127	5.8714	5.134	5.0015	0.9944	0.9883	0.9866
70	0.9868	0.9782	0.9786	0.9813	5.0118	4.5099	4.5260	4.6630	7.007	6.0305	5.8985	0.9982	0.9952	0.9945

Source: Author computations from Nigeria Census datasets.

Table 9. Estimation of parameters of Y-Transform for Male Populations using model stable population as standard

Age	C(x)			Cs(x)	Y(x)			Ys(x)	$\hat{Y}(x)$			$\hat{C}(x)$		
(x)	1963	1991	2006		1963	1991	2006		1963	1991	2006	1963	1991	2006
5	0.1675	0.1649	0.1622	0.1816	0.3383	0.3329	0.3272	0.3673	0.3398	0.3679	0.3409	0.1683	0.1819	0.1688
10	0.3227	0.3305	0.3078	0.3287	0.6692	0.6869	0.6362	0.6827	0.6463	0.6819	0.6369	0.3124	0.3283	0.3081
15	0.4384	0.4611	0.4270	0.4525	0.9406	0.9973	0.9124	0.9757	0.943	0.9718	0.9144	0.4394	0.4509	0.4278
20	0.5274	0.5628	0.5326	0.5572	1.1731	1.2738	1.1875	1.2575	1.2394	1.2492	1.1838	0.5509	0.5543	0.5313
25	0.6396	0.6372	0.6200	0.645	1.515	1.5069	1.4501	1.5334	1.5400	1.5192	1.4497	0.6469	0.6409	0.6199
30	0.7323	0.7114	0.6976	0.7184	1.8675	1.7801	1.7252	1.8087	1.8502	1.7873	1.7173	0.7283	0.7132	0.6956
35	0.8074	0.7745	0.7607	0.7795	2.2391	2.0629	1.996	2.0882	2.1756	2.0581	1.9912	0.7961	0.7735	0.7597
40	0.8551	0.824	0.8121	0.8302	2.5496	2.3386	2.2661	2.3776	2.5237	2.3369	2.2773	0.8516	0.8238	0.8140
45	0.9016	0.8683	0.8597	0.8721	2.9619	2.6524	2.584	2.6836	2.9041	2.63	2.5825	0.8961	0.8655	0.8594
50	0.9259	0.8987	0.8956	0.9064	3.2581	2.9313	2.8986	3.0139	3.3291	2.9445	2.915	0.9308	0.9000	0.8972
55	0.9502	0.9299	0.9287	0.934	3.6678	3.3158	3.2976	3.3777	3.8141	3.2884	3.2849	0.9568	0.9281	0.9278
60	0.9601	0.9443	0.9454	0.9559	3.8935	3.5522	3.5726	3.7921	4.3885	3.6773	3.7111	0.9755	0.9507	0.9523
65	0.976	0.9645	0.9645	0.9725	4.4097	4.0122	4.0127	4.2729	5.084	4.1243	4.2117	0.9877	0.9682	0.9708
70	0.9817	0.9736	0.9733	0.9846	4.6864	4.3136	4.3022	4.8588	5.9739	4.6633	4.8311	0.9949	0.9813	0.9842

Source: Author computations from Nigeria Census datasets.

Appendix 2c

Table 10. Estimation of parameters of Y-Transform for Male Populations using 2010 Ghana population as standard

Age (X)	C(x)			Cs(x)	Y(x)			Ys(x)	$\hat{Y}(x)$			$\hat{C}(x)$		
	1963	1991	2006		1963	1991	2006		1963	1991	2006	1963	1991	2006
5	0.1675	0.1649	0.1622	0.144	0.3383	0.3329	0.3272	0.2901	0.3123	0.3397	0.3153	0.1549	0.1682	0.1563
10	0.3227	0.3305	0.3078	0.2762	0.6692	0.6869	0.6362	0.5672	0.6178	0.6554	0.6124	0.2995	0.3164	0.2970
15	0.4384	0.4611	0.427	0.3991	0.9406	0.9973	0.9124	0.8451	0.9313	0.9634	0.9064	0.4347	0.4476	0.4245
20	0.5274	0.5628	0.5326	0.5081	1.1731	1.2738	1.1875	1.1204	1.2486	1.2600	1.1935	0.5541	0.5580	0.5347
25	0.6396	0.6372	0.6200	0.5997	1.5150	1.5069	1.4501	1.3852	1.5603	1.5373	1.4661	0.6528	0.6461	0.6249
30	0.7323	0.7114	0.6976	0.6781	1.8675	1.7801	1.7252	1.6512	1.8798	1.8078	1.7361	0.7352	0.7182	0.7004
35	0.8074	0.7745	0.7607	0.7438	2.2391	2.0629	1.996	1.9179	2.2067	2.0713	2.0032	0.8017	0.7762	0.7623
40	0.8551	0.8240	0.8121	0.8001	2.5496	2.3386	2.2661	2.1978	2.5565	2.3391	2.2794	0.856	0.8241	0.8143
45	0.9016	0.8683	0.8597	0.8477	2.9619	2.6524	2.584	2.4960	2.9370	2.6148	2.5693	0.8993	0.8636	0.8577
50	0.9259	0.8987	0.8956	0.8854	3.2581	2.9313	2.8986	2.8003	3.3338	2.8860	2.8603	0.9311	0.8943	0.8917
55	0.9502	0.9299	0.9287	0.9182	3.6678	3.3158	3.2976	3.1549	3.8065	3.1888	3.1933	0.9565	0.9208	0.9212
60	0.9601	0.9443	0.9454	0.9397	3.8935	3.5522	3.5726	3.4711	4.2377	3.4470	3.4846	0.9715	0.9383	0.9405
65	0.9760	0.9645	0.9645	0.9586	4.4097	4.0122	4.0127	3.8564	4.7755	3.7465	3.8327	0.9833	0.9539	0.9576
70	0.9817	0.9736	0.9733	0.9699	4.6864	4.3136	4.3022	4.1819	5.2401	3.9865	4.1205	0.9895	0.9635	0.9680

Source: Author computations from Nigeria Census datasets.

Table 11. Estimation of parameters of Y-Transform for Female Populations using 2010 Ghana population as standard

Age (X)	C(x)			Cs(x)	Y(x)			Ys(x)	$\hat{Y}(x)$			$\hat{C}(x)$		
	1963	1991	2006		1963	1991	2006		1963	1991	2006	1963	1991	2006
5	0.1756	0.1574	0.1596	0.1325	0.3549	0.3175	0.3219	0.2665	0.3075	0.3236	0.3004	0.1525	0.1604	0.1491
10	0.3236	0.3177	0.2988	0.2543	0.6713	0.6582	0.6164	0.5200	0.6127	0.6293	0.5886	0.2971	0.3047	0.2861
15	0.4209	0.4377	0.4093	0.3682	0.8977	0.9388	0.8694	0.7726	0.9292	0.9320	0.8782	0.4338	0.4350	0.4129
20	0.5207	0.5458	0.5158	0.4710	1.1546	1.2248	1.1413	1.0227	1.2547	1.2297	1.1671	0.5562	0.5475	0.5253
25	0.6575	0.6438	0.6200	0.5678	1.5768	1.5294	1.4501	1.2884	1.6139	1.5440	1.4768	0.6679	0.6481	0.6282
30	0.7651	0.7339	0.7167	0.6554	2.0166	1.8745	1.8015	1.5693	2.0084	1.8739	1.8070	0.7634	0.7338	0.7180
35	0.8454	0.8038	0.7885	0.7257	2.4797	2.2185	2.1349	1.8392	2.4018	2.1884	2.1269	0.8339	0.7984	0.7870
40	0.8867	0.8489	0.8416	0.7846	2.8127	2.5048	2.4534	2.1147	2.8179	2.5073	2.4564	0.8873	0.8493	0.8421
45	0.9267	0.8911	0.8859	0.8332	3.2688	2.8546	2.8053	2.3971	3.2599	2.8318	2.7971	0.9261	0.8887	0.8850
50	0.9443	0.915	0.9153	0.8716	3.5528	3.1146	3.1186	2.6795	3.7172	3.1537	3.1407	0.9525	0.9181	0.9171
55	0.9637	0.9416	0.9426	0.9063	3.9906	3.5034	3.5217	3.0131	4.2771	3.5308	3.5503	0.9726	0.9431	0.9442
60	0.9705	0.9524	0.9553	0.9273	4.200	3.7139	3.7780	3.2777	4.7366	3.8275	3.8782	0.9826	0.9574	0.9595
65	0.9827	0.9702	0.971	0.9470	4.7438	4.1914	4.2197	3.6038	5.3216	4.1902	4.2859	0.9903	0.9702	0.9729
70	0.9868	0.9782	0.9786	0.9595	5.0118	4.5099	4.5260	3.8786	5.8306	4.4933	4.6326	0.9941	0.9779	0.9807

Source: Author computations from Nigeria Census datasets.